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FUEL INJECTION SYSTEM

[0001] Prior Art

[0002] The invention is based on a fuel injection system as generically defined by the preamble to claim 1.

[0003] A common rail injector (CR stands for "common rail") with a piezoelectric actuator (or piezoelectric controller) and with boosting by hydraulic couplers is known. Integrated couplers with pistons disposed coaxially inside one another are also known. The known device uses an outward-opening valve as a control valve. This valve can be embodied with only a relatively small diameter, since otherwise the forces on the valve become too high, so that it cannot be actuated by a piezoelectric actuator.

[0004] Advantages of the Invention

[0005] The fuel injection system of the invention for internal combustion engines, having the definitive characteristics of claim 1, has the advantage over the prior art that a common rail injector with a piezoelectric actuator is created, in which a large cross section of the valve is possible. As a result, the opening and closing of the injection valve can be effected faster. The integrated coupler makes a short structural length of the device possible. The coupler is reinforced by CR pressure.

[0006] Drawing

[0007] One exemplary embodiment of the fuel injection system of the invention is shown in the drawing and described in further detail in the ensuing description. The sole figure shows the essential components of a fuel injection system of the invention, with an injection valve and a control valve as well as a hydraulic coupler.

[0008] Description of the Exemplary Embodiment

[0009] The fuel injection system 1 of the invention is supplied with fuel at high pressure by a pressure reservoir (common rail) 3 via a high-pressure line 5, from which fuel flows via an injection line 6 to reach an injection valve 9. An internal combustion engine normally has several such injection valves, and for the sake of simplicity only one is shown. The injection valve 9 has a valve needle (valve piston, nozzle needle) 11, which in its closing position, with a conical valve sealing face 12, closes injection openings 13 through which fuel is to be injected into the interior of a combustion chamber of the engine. The fuel reaches the vicinity of the nozzle needle via an annular nozzle chamber 14, from which, via a control face 15 embodied as a pressure shoulder, it makes it possible to exert a pressure in the opening direction of the nozzle needle. When this pressure exerts a force in the opening direction on the valve needle that overcomes forces acting counter to this opening, the valve opens.

[0010] For controlling the opening and closing of the injection openings, an actuator 31 is used. As a function of a triggering at a mechanical outlet, this actuator generates a

deflection and a force for actuating further elements. In this example, it is an electrically actuated actuator. In this example, it is an actuator which has a piezoelectric element, namely a piezoelectric actuator. The actuator takes on a lengthened configuration or a shortened configuration as a function of an electrical triggering in the vertical direction of the drawing, and thus in its own longitudinal direction. In this example, an actuator is provided with a construction such that when current is supplied (upon connection to a source of direct current), it assumes a lengthened configuration but without current it assumes a shortened configuration. The actuator forms a capacitive load, and when current is supplied continuously, it does not absorb any lost power. It may be advantageous or necessary to prestress the piezoelectric actuator by a tensing device, such as a spring, such that piezoelectric elements contained in the actuator are constantly in compression. This is familiar to those skilled in the art and will therefore not be discussed below. While the upper end of the piezoelectric actuator is anchored in the injection device in a manner not visible in the drawing, the lower end of the piezoelectric actuator serves to use its force and motion in the final analysis for opening and closing the injection openings. To that end, a hydraulic coupler 38 is provided for its coupling; the hydraulic coupler has one piston 39 coupled to the piezoelectric actuator and one further piston 40. In the present application, by means of the coupler, an increase in the travel of the further piston 40 in comparison to the travel of the piston 39 is generally necessary (by means of a suitable choice of the hydraulically operative piston areas). The construction and mode of operation of the hydraulic coupler will be described hereinafter.

[0011] When the piston 40 of the hydraulic coupler that is not directly connected to the piezoelectric actuator opens a control valve 41 (or outlet valve), the pressure in a fuel-filled control chamber 43, the inside of which is engaged by the upper end portion of the nozzle needle, drops. The control chamber 43 is filled with fuel underpressure via an inlet throttle 47, and when the control valve 41 is opened, fuel flows out of the control chamber 43 via an outlet throttle 49. The outflow of fuel is reinforced by forces that seek to move the nozzle needle 11 into its open position. When the control valve 41 is closed, a movable valve piece 51 rests in sealing fashion on a valve seat 53 and is mechanically coupled to the piston 40. The control quantity flowing out of the control chamber when the valve piece 51 is opened is carried away through a leak fuel conduit 55. When the valve piece 51 is closed, it is acted upon from the control chamber by rail pressure (that is, pressure in the line 5); the pressure acts on the face having the diameter d3.

[0012] The pistons 39 and 40, in this example, are parallel to one another and inside one another, coaxially inside one another (integrated coupler), which is advantageous from a production standpoint. The way in which they are coupled to one another will be explained hereinafter. An arrow is shown in the piston 39, indicating the motion of this piston when the actuator executes a motion downward in terms of the drawing. In the piston 40, an arrow is shown which indicates the motion of that piston when the piston 39 executes its motion indicated by its arrow. By comparing the arrow of the piston 40 with the direction in which the movable valve element of the valve, to be actuated by the hydraulic converter 38, must be moved for opening and for closing, it can be seen directly from the drawing whether the direction shown in the drawing by

the aforementioned arrows corresponds to an opening event or a closing event of the aforementioned valve.

[0013] The movable valve piece 51 is embodied essentially conically, with a cylindrical extension. In particular, in the closed state, it rests with a conical part on the valve seat 53. The valve piece 51 is prestressed in the direction of its valve seat 53 by a compression spring 54 that is guided by the cylindrical extension. In its blocking position, it has been moved "outward", namely in the direction from the high pressure in the control chamber 43 to a region of lower pressure (leak fuel pressure). The outlet valve is in this case therefore called an outward-opening valve. The side of the valve piece 51 facing toward the valve seat 53 is rigidly connected to an actuating part that is connected to the hydraulic coupler. The connection to the piston 37 is advantageously tensionproof, for the sake of especially fast closing.

[0014] The actuator 31 is connected to the piston 39 by a rod 61 having a diameter d5. The piston 40 is connected to the movable valve part 51, to be actuated by it, by a rod 63 having a diameter d1. The inner piston 39 has a diameter d4; the outer piston 40 has a circular piston face whose area is f2. The inside diameter of the valve seat 53 at the place where the movable valve part rests on it is d3.

[0015] Guide gaps 65 and 67, which serve to guide the piston in sliding fashion and through which a coupler volume is filled with fuel, are formed in the region of the cylindrical outer face of the outer piston (diametrically opposite a housing, not shown) and in the region of the mutual sliding guidance of the two pistons.

[0016] The areas f1, f3 through f5 corresponding to the aforementioned diameters d1, d3 through d5 (for circular cross sections) and the aforementioned area f2 are definitive for the function. Circular cross sections are indeed expedient from a production standpoint, but the invention is not limited to them.

[0017] The end regions of the pistons 39 and 40 oriented toward the actuator 31 engage the inside of a common booster chamber 72. The other end region of the piston 39 engages the inside of a filling chamber 71-2; this chamber communicates via bores in the lower end wall of the piston 40, which communicates with the line 5. The other end region of the inner piston 40 protrudes into the filling chamber 71-2. Via the guide gaps 65 and 67, the booster chamber 72 is filled. The booster chamber 72 is penetrated by the rod 61. The filling chamber 71-1 is penetrated by the rod 63. The pistons 39 and 40 move in opposite directions from one another, and they also, because of the desired travel boosting from the actuator to the control valve, move at different speeds.

[0018] The actuator 31 (piezoelectric controller) is supplied with current and lengthened, in the closed state of the injection valve 9. For opening the control valve 41, the electric current to the actuator 31 is switched off, and the actuator becomes shorter. As a result, the piston 39 (first booster piston) is moved upward in the drawing, reinforced by the spring 75 and by the pressure in the filling chamber 71-2. In the booster chamber 72 and in the filling chamber 71-2, CR pressure (that is, pressure of the pressure reservoir or common rail) is as system pressure in the state of repose. In the booster chamber, as a result with the upward motion of the piston 39, the pressure increases. This pressure increase moves the piston 40 (second booster piston)

downward and, by motion of the valve part 51 oriented in the same direction, opens the control valve 41, which is an outward-opening valve. For fast closure of the valve part 51, this part is preferably solidly connected to the rod 63 and thus to the piston 40. Because of the CR pressure in the booster chamber 72, the seat diameter d3 of the valve part 51 can be selected to be quite large, since the piston 40 largely compensates for this area with its side located in the booster chamber 72. The invention thus creates an advantageous outward-opening valve/servo injector with CR pressure reinforcement for very fast opening and closing of the injection valve. The coupler assures a short structural length.

[0019] One important characteristic of the invention is that rail pressure is applied to the side of the piston 39 (in the booster chamber) that faces away from the control valve; this rail pressure reinforces the actuation of the control valve and acts counter to the pressure exerted from the control chamber 43 on the valve part 51 in the blocking state.

[0020] Because of the rail pressure in the booster chamber 72, d3 is largely force-balanced. In comparison to the prior art, a greater excess of force, which is furnished by the actuator to accelerate the mass of the movable valve part, is therefore available. The invention accordingly creates a variant with a partially-compensated (= partially balanced relative to the force) control valve, and this valve is an outward-opening valve. The force to be furnished by the actuator for closing the valve is therefore less than in the known art. Instead, in one version, a valve 51 with a greater diameter d3 than in the known art is provided, which enables a faster opening and closing of the

injection valve, because the increase and decrease in the flow in it is greater than in the known, smaller outward-opening valve.

[0021] A compression spring 75 in the filling chamber 71-2 forces the pistons apart and assures good contact of the coupler with the actuator 31 and, when the valve is closed, of the valve part 51 on the valve seat 53.

[0022] The system shown has still further characteristics. At least in one region of the rod 61, connecting the actuator 31 to the hydraulic coupler, at a distance from the chamber of the coupler closest to the actuator 31, there is a further filling chamber 90, which communicates with the line 5. In this example, the further filling chamber 90 surrounds the actuator 31 in its lower end region. Preferably, it surrounds the entire actuator 31. A guide gap 94 of the rod 61 is dimensioned for additional filling of the adjacent chamber of the coupler with fuel that is under pressure. One advantage is in the additional filling of the coupler with fuel that is at high pressure.

[0023] In some versions of the invention the further filling chamber 90 is either not present or does not communicate with the line 5 and does not have the function of a filling chamber. In that case it may be expedient for a bore, in which the rod 61 is guided in a housing, not shown, of the entire system, to be dimensioned for the least possible outflow of fuel from the coupler.

[0024] The invention also includes versions in which the fuel that is at high pressure is not delivered from a high-pressure reservoir but rather from a pump associated with the injection valve (such as a unit fuel injector) that also supplies the filling chamber.